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ABSTRACT

Three studies of cooperative problem solving among university students examined how to design effective computer-based support for collaborative learning in distance education. The first was a questionnaire study of 150 Open University students who had participated in three different courses in physics and mathematics. Its aim was to determine students' participation in and preferences for cooperative work in their courses. The main finding was that although students expressed a preference for working alone, many participated in collaborative work in their courses and regarded such activities as helpful. More detailed investigation was needed to determine the nature of collaborative activities in which these students engaged and the ways in which they found them helpful. An observational study of group activities at summer school and a comparison of the use of two different kinds of interface for supporting synchronous cooperative problem solving were then conducted. The characteristics of successful divisions of labor observed in noncomputer-based activities suggested that one issue related to designing computer support for such problem solving is how to design appropriate tools and representations for joint activity. (Appendixes include 28 references and 5 figures.) (YLB)

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Computer-supported collaborative learning: Problem solving and distance education

Claire O'Malley & Eileen Scanlon

CITE Report No. 75

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Computer-supported collaborative learning: Problem solving and distance education

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Abstract

The aim of this research is to understand how to design effective computer-based support for collaborative learning in distance education. This paper reports on three preliminary studies of cooperative problem solving among university students. The first is a questionnaire study of Open University students, the aim of which was to determine their participation in and preferences for cooperative work in their courses. The main finding was that although students expressed a preference in general for working alone as opposed to collaboratively, many of them did participate in collaborative work in their courses, and regarded such activities as helpful in their work. A more detailed investigation was indicated in order to determine the nature of collaborative activities that these students engaged in and the ways in which they found them helpful. Two studies are described, one of which was an observational study of group activities at summer school. The other study compared the use of two different kinds of interface for supporting synchronous cooperative problem solving. The implications from these studies are discussed in relation to designing computer support for collaborative learning.

This paper was presented at the CAL89 conference, University of Surrey, 11-14 April, 1989.

Introduction

Physics problems solving

The aim of this research is to understand how to design effective computer-based support for collaborative learning in distance education. The domain chosen for this research is problem solving in physics and applied mathematics. Novice physics students have erroneous ideas about even basic concepts in physics. Students' problems derive partly from instructional methods, which tend to emphasise formal expressions of physical laws [1]. Research has shown that expert problem-solving usually begins with a causal (qualitative) analysis of the problem; quantitative solutions are only developed after the problem has been analysed and understood in causal terms [2,3]. Students may have difficulty linking the formal methods they are taught with their informal everyday experiences, which don't always allow students to induce the correct laws, leading to the development of inappropriate models. Furthermore, students often develop several conflicting models (derived from different contexts) to account for different aspects of the domain. This is encouraged by the fact that real-world experience is highly complex, as in three-dimensional motion, where multiple forces (friction, gravity, etc.) act simultaneously, and where the changes in motion that result from these forces act too quickly for us to distinguish.

Physics educators differ about whether possession of these misconcepts is sufficient to explain students' unsuccessful problem solving, and whether these misconcepts should more properly be described as alternative conceptions of the physical world. However, it is clear that the task of successful physics instruction has to involve ways of making students reassess their conceptual systems or models of the world, and to address the question of whether there are distinct teachable problem solving skills which students have to learn.

One way of encouraging students to reflect on their own models is to allow them to manipulate the relevant constraints and variables individually, altering them and experimenting to see how they interact. In other words, conceptual change in learning physics may be facilitated by revealing to learners the inconsistencies or conflicts amongst their different models [4]. However, simply confronting students with such conflicts is no guarantee that they will abandon their naive conceptions [5, 6], even when they are actively involved in exploring the consequences of their own models. Learners may find it easier to misinterpret or distort information to fit their models than to change their models to fit the data [7,8].

The value of peer interaction for learning and problem solving

There is some reason to believe that problem solving in pairs or in groups is more likely to produce the kind of conflicts that may lead to conceptual

change. However, the overall experimental evidence concerning the effects of cooperative activity on individual learning and development is somewhat equivocal. Benefits appear to be dependent on a number of task-specific factors [9,10,11]; research findings are not always replicated; and researchers are divided about the underlying mechanisms responsible for cognitive change [5, 12, 13, 14].

Researchers within the (neo-)Piagetian tradition have argued for conflict-based mechanisms, based on Piaget's early work on decentration. Doise and Mugny [15] are perhaps the best-known for this approach. They argue that it is in the coordination of the child's actions with those of others that the individual acquires mastery of systems of coordinations which are later individualised and internalised. Thus, in terms of the theory of socioconstructivism, when a child interacts with another in solving a problem the difference between them produces conflict which forces each child to restructure his or her representations or alter strategies to resolve the conflict. The mechanism for this internalisation is conflict-based (and therefore Piagetian), but it is socio-cognitive, rather than simply intramental conflict.

The theory of Doise and Mugny is similar in some respects to that of Vygotsky, who saw cognitive development as proceeding from the interpsychological to the intrapsychological, and therefore shares the view about the causal nature of the relationship between the social and the cognitive. The two positions differ, however, with respect to the mechanisms responsible for interiorisation. Whereas Doise and Mugny emphasise the importance of sociocognitive conflict, the Vygotskian tradition emphasises the importance of the notion of the "zone of proximal development" (ZOPD) and research following this tradition tends to emphasise notions such as "scaffolding" and "apprenticeship" as facilitators in social interaction [16,17]. Vygotsky's theory is also heavily based on semiotics, and the emphasis is on the role of language (including nonverbal symbolic forms) as a mediator of development (a notion which is taken up, for example, in the work of Edwards and Mercer [18]).

Other researchers have argued for effects of the child's perception of the social context — i.e., the role of "pragmatic schemas" mediating performance in collaborative activity, whilst others have argued for modelling as a basis for change. The latter claim is similar to the Vygotskian approach.

Despite their differences, researchers within both the Vygotskian and Piagetian traditions argue that social interaction is only likely to be effective when there are some initial differences in perspectives between the members of the dyad, corresponding to what Wertsch calls different "situation definitions" [17]. In fact, there doesn't seem to be any fundamental theoretical difference between these two approaches, it's more a difference in emphasis. The emphasis in the Vygotskian perspective is

fundamentally social, and concerns the nature of the interaction; the emphasis in the sociocognitive perspective is more on individual (intrapsychological) change, and the mechanisms that bring such change about.

The notion of conflict as a mechanism for conceptual change is unsatisfactory for several reasons: there is no explanation for how conflict is perceived and resolved, nor why there is an impetus to resolve it. Furthermore, it is possible that learning can take place in peer interaction without there being any conflict. Even where there are differences in schemas or models of the task, these may not necessarily compete or be inconsistent with each other, they may actually be alternative perspectives or viewpoints which contribute equally to the problem solving task.

Researchers who adopt the apprenticeship model tend to emphasise relationships between participants which are assymmetrical — that is, one partner "knows more" than the other. In this view, cognitive change takes place within the "zone of proximal development", where what the child (or less able peer) can do with assistance eventually becomes interiorised so that the task may be performed eventually without help. However, in many cases it isn't clear how to measure the "amount of knowledge" each partner has. A more appropriate view may be that each participant contributes something to the solution of the problem. Thus, in joint problem-solving situations, because there are two (or more) people working on the problem, there is more of a possibility for alternative perspectives or interpretations, which stimulates participants into articulating their point of view and using it to argue and criticise the other's point of view. The process of being confronted with a different point of view helps one to overcome "cognitive hysteresis" (a term which captures the notion of "functional fixity", while also capturing the phenomenon of perseveration of wrong solutions [19]).

During the collaborative activity, various discourse rules to do with the maintenance of dialogue focus mediate the focus of the joint activity. In her studies of cooperative problem solving, Miyake [20] found that subjects appeared to take different roles depending on their different focus or point of view. So, while one person led the interaction by engaging in a local task, the other observed and provided help by criticising and suggesting new ways of approaching the problem. The leader/follower or taskdoer/observer pattern has also been found in studies by Garrod & Anderson [21], involving maze-following coordination tasks. This division of roles facilitates problem solving in that, because each participant works from a different perspective, what is natural and obvious for one may not be so for the other. In contrast, it can be difficult to come up with counter examples in individual problem solving.

Computer-supported collaborative learning

There's a tremendous interest at the moment in group work with computers, but the systems involved in most of the studies reported in the literature (except for studies of conferencing systems) have been designed for individual, not collaborative use. In these cases, it isn't clear what role the computer is playing in the collaborative activity. It's one thing to claim that collaboration may enhance learning via computer-based activities, but quite another to claim that a collaborative computer-based activity is different in some essential way to any other collaborative activity. Current hardware configurations typically result in collaboration being restricted to talking about the activity and doing some sort of turn taking with the mouse/keyboard.

Several studies have shown that active involvement in the collaborative activity is important for success. Studies by Crook [10] have shown that the nature of the task is an important factor in making the interaction constructive for each of the participants. One of the tasks he investigated was a maze following game. This task required distributing attention between the maze itself and the sequence of steps being written to traverse it. Most children were reluctant to do this at times when they weren't keying in the instructions themselves, so collaboration rarely went beyond taking turns at the whole task. Another task involved solving anagrams — here there was a tendency for one child to spot the solution immediately, leaving the other to just key it in. The successful tasks involved having to construct or discover rules, such as completing series, or an adventure game. In these tasks, the approach to the solution was more differentiated, prompting discussion of competing hypotheses.

However, although most of the work on synchronous collaborative use of computers has involved the use of systems designed for individual activity (both in terms of software and hardware) some researchers have attempted to exploit them for cooperative usage. Blaye [22] structured a paired interaction so that one child indicated his or her choice in a form/colour matrix filling task with a lightpen and the other had to key in his or her agreement via the keyboard before the instruction would be accepted by the computer. Light, Foot, Colbourn & McClelland [11] modified the keyboard so that corresponding key entries were required from both participants to activate a response. This "dual key" condition, resulting in joint participation of both children in every move, was associated with peer facilitation of individual performance.

In considering the design of computer-based support for cooperative learning there are two main issues: how to construct an environment in which learners can share representations and contribute equally to the joint activity; how to design the appropriate representations and tools which will make it possible for learning to take place. Some research is underway concerning the design of interfaces to support collaborative activities [23], but

little that provides guidance on ensuring an educationally effective design. A good deal of research exists on designing individual computer-based learning activities, but this research is not enough in itself to provide principles for designing collaborative support.

The variety of approaches to computer-based learning can be described in terms of a continuum from directive teaching (e.g., computer tutors) to discovery learning (e.g., microworlds) [24]. Arguments for the former tend to stress adaptivity; arguments for the latter tend to emphasise expressivity. Arguments for both kinds of approach are based on inherently individualistic assumptions about the units of user-computer interaction. When one considers how the computer might support collaborative (as opposed to individual) activity, other roles become appropriate. One possibility is for the computer to act as a medium for joint activity (e.g., networking); another perspective is that the computer acts as a cooperative agent in the performance of tasks. A third view is that the computer is a tool for cooperative activity. These views are not mutually exclusive. An important objective of our research is to develop a theoretical framework for understanding joint activity, in order to make principled decisions about the design of such systems.

Cooperative problem solving in distance education

The immediate educational context to which this research is applied is the Open University. There are no pre-requisites for entry into the Open University system and, consequently, many students find mathematics in general and physics problem-solving in particular extremely hard. We were interested in investigating whether or not group work would provide the conditions in which OU students could get over some of their difficulties in problem solving in these domains.

On the surface, it may seem odd to think about group work for OU students, since one of the reasons for people enrolling in OU courses is that they cannot attend courses designed for groups. However, the recently adopted home computing policy means that in the very near future OU students could be linked via home computers to each other. OU students of the future need not be separated from each other or their tutors because of distance and time constraints.

A study of OU students' attitudes to cooperative problem solving

A questionnaire was sent to 150 OU students who had participated in three different courses in physics and maths (50 in each course). One of these was a foundation course in maths, another was a second-level maths course, which laid more emphasis on applied mathematics than the foundation course. The two courses were similar in that both included direct teaching of problem-solving and modelling skills, although the particular models taught were different. The two courses also differed in the amount and

nature of group work undertaken at summer school. The third course was a second level physics course, which contained a fair amount of applied mathematics. Students in this course are not given explicit teaching of problem solving or modelling, but they are given a good deal of practice at solving problems. This course differed from the two maths courses in that there was less emphasis on cooperative activity, although some group work was undertaken at summer school.

The two main groups of academics responsible for instruction in this area adopt quite different approaches. The physicists rely on very large amounts of practice with feedback on accuracy of solution being provided via answers at the 'back' of correspondence texts, computer worked assignments and marked work returned by human tutors. Their summer school work includes group work on problem based videodisk.

The mathematicians adopt a quite different approach and aim to teach problem solving explicitly. Beginning students are required to undertake exercises which help them reflect on their own ways of trying to solve problems. In the course of these activities they acquire a vocabulary of terms for problem solving states and processes; they are taught to distinguish generalising from specialising and the difference between various proof methods. Towards the end of their introductory course, they are taught a seven stage model of the mathematical modelling process that is recursive and based on the idea of progressively refining problem solutions. They have an opportunity to examine and apply this work in group problem solving sessions run at the courses summer school. The subsequent applied mathematics course includes a substantial modelling project and the students are helped by examples of real student work and video material depicting groups of experts trying to solve surprise problems, again combined with summer school group problem solving sessions [25].

80 out of the 150 students returned the questionnaire — a roughly even split between the three groups under investigation.

Our main interest in this study was in finding out to what extent students participated in collaborative work during their courses, and their perceptions of the value of group work. A secondary interest was in investigating the influence of direct teaching of problem solving skills on performance in individual and group work. The latter issue is still under investigation. The following discussion relates to students' perception of group work only.

Students preferences for group work

When students were asked about their preferences for working alone or in groups, over 75% of respondents expressed a preference for individual work

(see Figure 1). There was no significant difference between the three groups ($\chi^2 = .486$, $p = .81$).

Over 80% of the maths students had taken part in group work at summer school, and about 65% of the physics students (see Figure 2). When these students were asked about the value of summer school group work, most of the physics and foundation-level maths students fround it effective, but the second-level maths students were less enthusiastic (Figure 3). However, the differences between these groups was not significant ($\chi^2 = 8.48$, $p = .21$)

The most interesting question from our point of view concerned the extent to which students engaged in group work that wasn't structured for them. When asked about voluntary participation in self-help study groups (not tutorials), about half of the foundation-level maths students had taken part in these, but only 25% of the second-level maths and physics students (Figure 4). Again, there were no significant differences between the three groups ($\chi^2 = 3.35$, $p = .19$).

Of these students, the mathematicians tended to meet more frequently than the physicists and in smaller groups (mostly pairs — Figures 5 and 6). The most frequent size of groups for physicists was 3-5 people, whereas the mathematicians worked in pairs more often. (The sample sizes of these groups were too small to make a statistical comparison.) When asked about the value of self-help study groups the majority of students felt that they were helpful, with the foundation-level maths and the physics students being slightly more enthusiastic than the second-level maths students (Figure 7).

Conclusions from questionnaire study

In summary, when asked about their preferences in general, the vast majority of students who responded to the questionnaire said they preferred to work alone rather than in groups. However, most students did participate in organised group work at summer school, and most of them (apart from the second-level maths students) found this helpful. More interesting from our point of view is the finding that just over one third of the students who responded had taken part in voluntary group work during the course of the year, and the majority of these found it valuable.

Two general conclusions may be drawn (tentatively) from this study. One is that, despite a general preference for individual work (consonant with distance learning in general), a fairly high proporation of OU students find value in group activity. The other conclusion (as indicated by a difference in attitude between foundation-level and second-level maths students) is that the appropriateness of group activity may depend on the nature of the course which students are studying.

An observational study of collaborative work at summer school

In order to investigate the nature of these group activities in more detail, we took a videocamera to two summer schools involving students on each of the courses we had examined in the questionnaire study. Our analysis is still to be completed, but initial findings raise some interesting issues for thinking about the design of computer support for group problem solving.

In general, the size of the groups at summer school tended to be quite large — ranging from four to about six. However, within these groups, students tended to split up into pairs or threes, with the occasional student working separately, but keeping in touch with the activities of the rest of the group. (Note that these were the preferred sizes of self-help groups for the mathematicians. This is also consistent with findings by Trowbridge [26] that working in twos or threes produces higher levels of interaction than larger groups, though those working in threes are more likely to show competitive interaction. Pairs tend to be more mutually supportive and perform better than larger groups.)

The nature of the task and the tools or representations which students were given for solving the problem tended to influence the way in which the overall activity was divided. Pencil and paper tasks tended to result in duplication of effort when the groups divided into smaller groups of two or three. However, in cases where the task involved the use of different measuring devices or representations, students tended to divide the task into non-overlapping subtasks and then compare results from these different activities to produce a hypothesis for the solution. This led to a variety of different viewpoints on the task being discussed. These kind of groups tended to produce much livlier arguments and a deeper appreciation of the problem space, compared with those involved in the pencil and paper activities.

An observational study of small group problem solving in physics

We were interested in examining in more detail the effects of alternative representations on group problem solving and the effects of tools and task structure on these representations. We conducted a study in a more structured setting than the summer school study, where groups of three people were given physics problems to solve collaboratively. We used a variety of problems, each of which were characterised by the fact that they were stated as "real world" problems, rather than standard textbook problems. Our analyses are not complete, but an initial look at the data suggests some interesting issues concerning alternative representations and their role in group problem solving.

An example of one task given to subjects was to determine by how much a length of rope would shorten when a single overhand knot was tied in it, and why. This task is one of a series of such tasks developed for the second

level mathematical modelling course [25]. Subjects were given several lengths of rope, of varying thicknesses, to examine, rulers for taking measurements, and a large whiteboard and sheets of paper for making notes or drawing diagrams. In general subjects in this task tended to divide into ones and twos. One person would concern themselves with collecting data from experiments with the materials provided (i.e., measuring ropes of various thicknesses). The pair would concentrate on trying to model the problem qualitatively (i.e., examining the topology of the knot). As the individual came up with a pattern in the data, he or she would submit this information to the pair. The pair would switch between examining the tools provided, and modelling it on paper in a schematic way. This task was often divided up between the subjects in the pair, so that the activities were done in parallel. This often produced lively argument about the correctness of a given model.

In general, then, our study suggests that successful collaborative problem solving involves the possibility of generating alternatives representations of the problem, and that this is influenced by the tools provided for solving the problem.

Computer support for collaborative problem solving

A study of cooperative adventure games

The characteristics of successful divisions of labour we have observed in non-computer-based activities suggests that one issue designing computer support for such problem solving is how to design appropriate tools and representations for joint activity. We have conducted some studies of the use of two existing collaborative adventure games: Gauntlet (a "dungeons and dragons" game for up to four players on the Atari-ST) and Xybots (a D&D video arcade game for two players — also by Atari). Our interest in this study has been twofold: we have been analysing the way in which the representation of the "shared space" influences cooperation. Gauntlet uses a single "bird's eye" representation of the shared space, whereas Xybots, in addition to providing a shared representation (in the form of a map of the levels), gives users representations of their individual spaces — they can "see" the other person when they are in the same area, but only from their point of view.

Although the non-computer-based work we have discussed indicates that the ability to divide the task in this way is important for successful achievement of the shared goal, preliminary results from the computer-based work suggest that cooperation is better with the more impoverished representation of Gauntlet. We suspect that this is affected by attentional contraints in using multiple representations. The problem is compounded in the kind of "shoot-em-down" games we were observing, since users have to respond very quickly to what's happening on the screen. We are

currently investigating this in more detail and manipulating representations given to subjects under experimental conditions.

Summary and conclusions

Our studies of OU students suggests that there is value, both perceived and actual, in synchronous group activities, despite the inherently individual character of distance learning. Computers are beginning to play a significant role in OU courses, and are likely in the future to have even greater significance for distance learning in general. Work is going on at the OU on providing computer-based conferencing facilities for asynchronous collaborative learning amongst OU students [27]. Our concerns have been with the support of synchronous distributed problem solving, and the design of future distributed systems for distance education. We are investigating the potential of such a system for synchronous distributed problem solving — Shared ARK [28]. Clearly, the technology, although widely available in research environments, is not yet accessible to OU students working on small microcomputers. However, with the pace of change in technology and the trend towards more and more powerful small machines, this kind of research is urgently needed if we are to understand how to design the systems that will be accessible a couple of years hence.

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References

[1] White, B.Y. & Horwitz, P. (1987) ThinkerTools: Enabling children to understand physical laws. Report No. 6470, BBN Laboratories, Cambridge, MA.

[2] Chi, M., Feltovich, P. & Glaser, R. (1981) Categorization and representation of physics problems by experts and novices. *Cognitive Science, 5,* 121-152.

[3] Larkin, J.H., McDermott, J., Simon, D.P. & Simon, H.A. (1980) Expert and novice performance in solving physics problems. *Science, 208,* 1335-1342.

[4] Anzai, Y. & Yokoyama, T. (1984) Internal models in physics problem solving. *Cognition and Instruction, 1,* 397-450.

[5] Bryant, P. (1982) The role of conflict and agreement between intellectual strategies in children's ideas about measurement. *British Journal of Psychology,* 73, 243-251.

[6] Norman, D. (1983) Some observations on mental models. In D. Gentner & A. Stevens (Eds.) *Mental Models*. Hillsdale, N.J.: Lawrence Erlbaum Associates.

[7] Riley, M. (1986) Users' understandings. In D. Norman & S. Draper (Eds.) *User Centered System Design*. Hillsdale, N.J.: Lawrence Erlbaum Associates.

[8] Lewis, C. (1986) Understanding what's happening in system interactions. In D. Norman & S. Draper (Eds.) *User Centered System Design*. Hillsdale, N.J.: Lawrence Erlbaum Associates.

[9] Fletcher, B.C. (1985) Group and individual learning of junior school children on a microcomputer-based task: Social or cognitive facilitation? *Educational Review, 37*, 251-261.

[10] Crook, C. (1987) Computers in the classroom: Defining a social context. In J.C. Rutkowska & C. Crook (Eds.) *Computers, Cognition and Development*. Chichester: Wiley.

[11] Light, P., Foot, T., Colbourn, C. & McClelland, I. (1987) Collaborative interactions at the microcomputer keyboard. *Educational Psychology, 7*, 13-21.

[12] Emler, N. & Valiant, G.L. (1982) Social interaction and cognitive conflict in the development of spatial coordination skills. *British Journal of Psychology, 73*, 295-304.

[13] Glachan, M. & Light, P. (1982) Peer interaction and learning: Can two wrongs make a right? In G. Butterworth and P. Light (Eds.) *Social Cognition*. Brighton: Harvester Press.

[14] Russell, J. (1982) Cognitive conflict, transmission, and justification: Conservation attainment through dyadic interaction. *Journal of Genetic Psychology, 140*, 283-297.

[15] Doise, W. & Mugny, G. (1984) *The Social Development of the Intellect*. Oxford: Pergamon Press.

[16] Forman, E. & Cazden, C. (1983) Exploring Vygotskian perspectives in education: The cognitive value of peer interaction. In J.V. Wertsch (Ed.) *Culture, Communication and Cognition*. New York: Cambridge University Press.

[17] Wertsch, J.V. (1984) The zone of proximal development: Some conceptual issues. In B. Rogoff & J. Wertsch (Eds.) *Children's Learning in the "Zone of Proximal Development"*. San Francisco: Jossey-Bass.

[18] Edwards, D. & Mercer, N. (1987) *Common Knowledge*. London: Methuen.

[19] Lewis, C. & Norman, D. (1986). Designing for error. In D. Norman & S. Draper (Eds.) *User Centered System Design*. Hillsdale, N.J.: Lawrence Erlbaum Associates.

[20] Miyake, N. (1986) Constructive interaction and the iterative process of understanding. *Cognitive Science, 10*, 151-177.

[21] Garrod, S. & Anderson, A. (1987) Saying what you mean in dialogue: A study in conceptual and semantic co-ordination. *Cognition, 27*,

[22] Blaye, A. (1988) Confrontation socio-cognitive et résolution de problème. Unpublished doctoral thesis, University of Provence.

[23] Greif, I. (1988) (Ed.) *Computer-Supported Cooperative Work*. San Mateo, CA: Morgan Kaufmann.

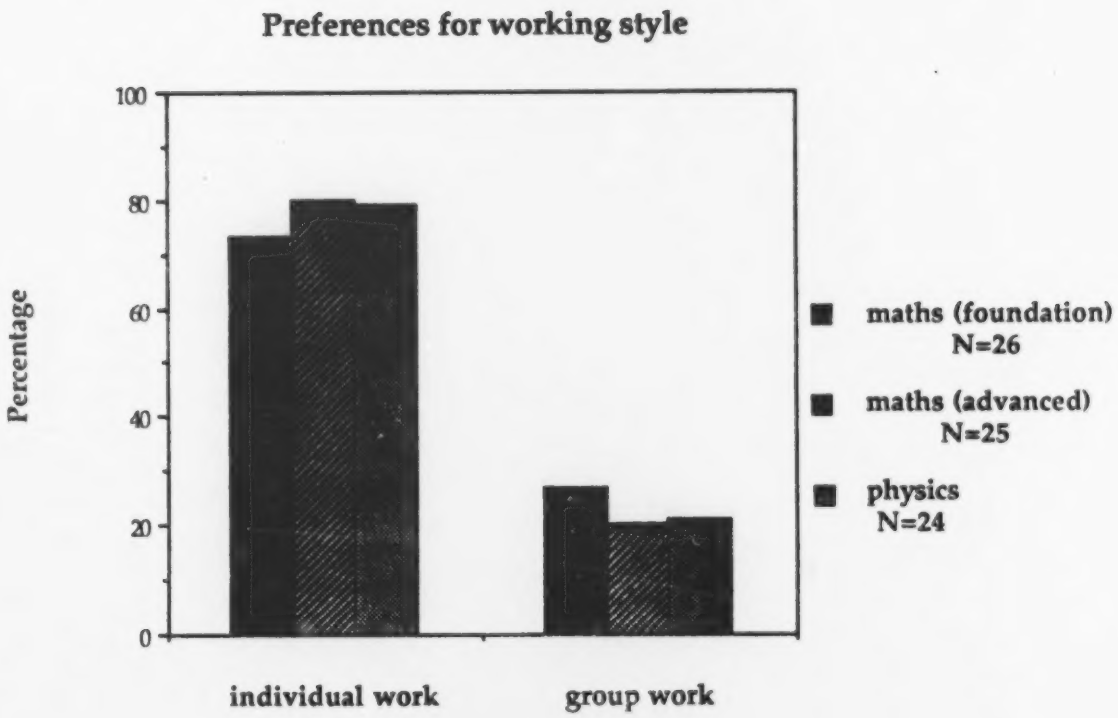
[24] O'Shea, T., O'Malley, C. & Scanlon, E. (1988) Magnets, martians and microworlds: Learning with and learning by OOPS. CITE Technical Report No. 53, Institute of Educational Technology, The Open University.

[25] Berry, J. & O'Shea, T. (1984) Mathematical modelling at a distance. *Distance Education, 5* (2), 163-173.

[26] Trowbridge, D. (1987) An investigation of groups working at the computer. In K. Berger, Pezdek and Banks, W. (Eds.) *Applications of Cognitive Psychology: Problem Solving, Education and Computing*. Hillsdale, N.J.: Lawrence Erlbaum Associates.

[27] Mason, R. (1988) The use of computer-mediated communication for distance education at the Open University, 1988. CITE Technical Report No. 56, Institute of Educational Technology, The Open University.

[28] Smith, R. (In press) A prototype futuristic technology for distance education. In E. Scanlon & T. O'Shea (Eds.) *New Directions in Educational Technology*. Springer.


Preferences for working style
100
80
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Percentage
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group work
maths (foundation)
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maths (advanced)
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physics
N=24

Figure 1

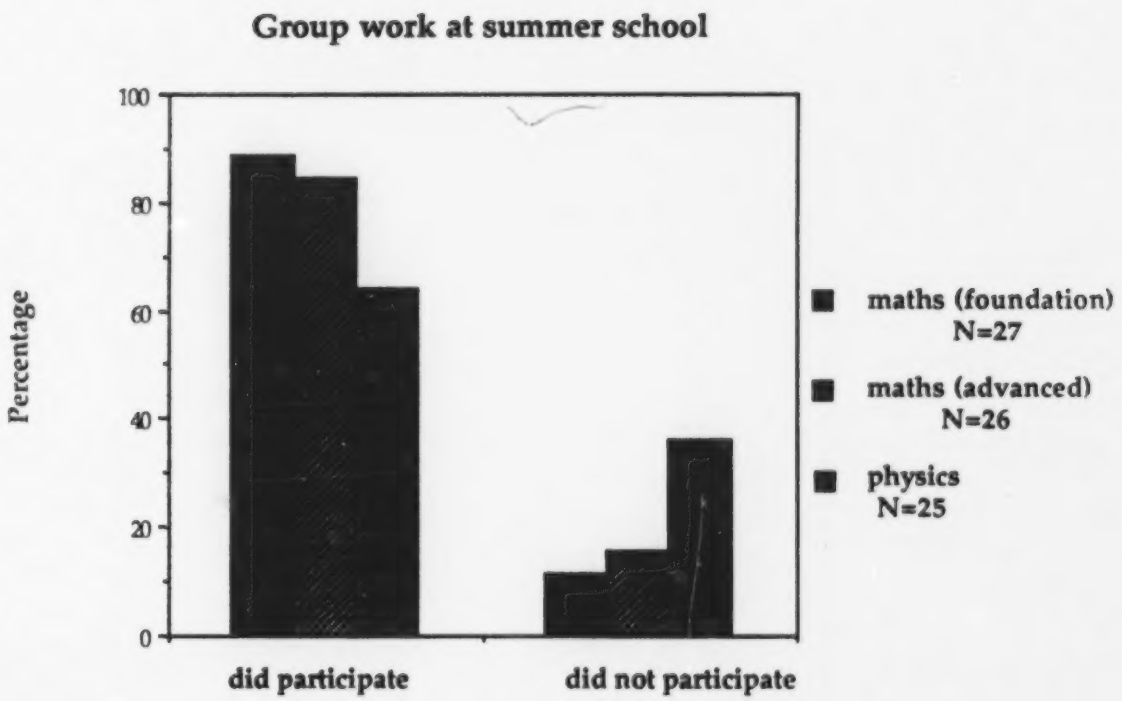
Group work at summer school
Percentage
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Figure 2

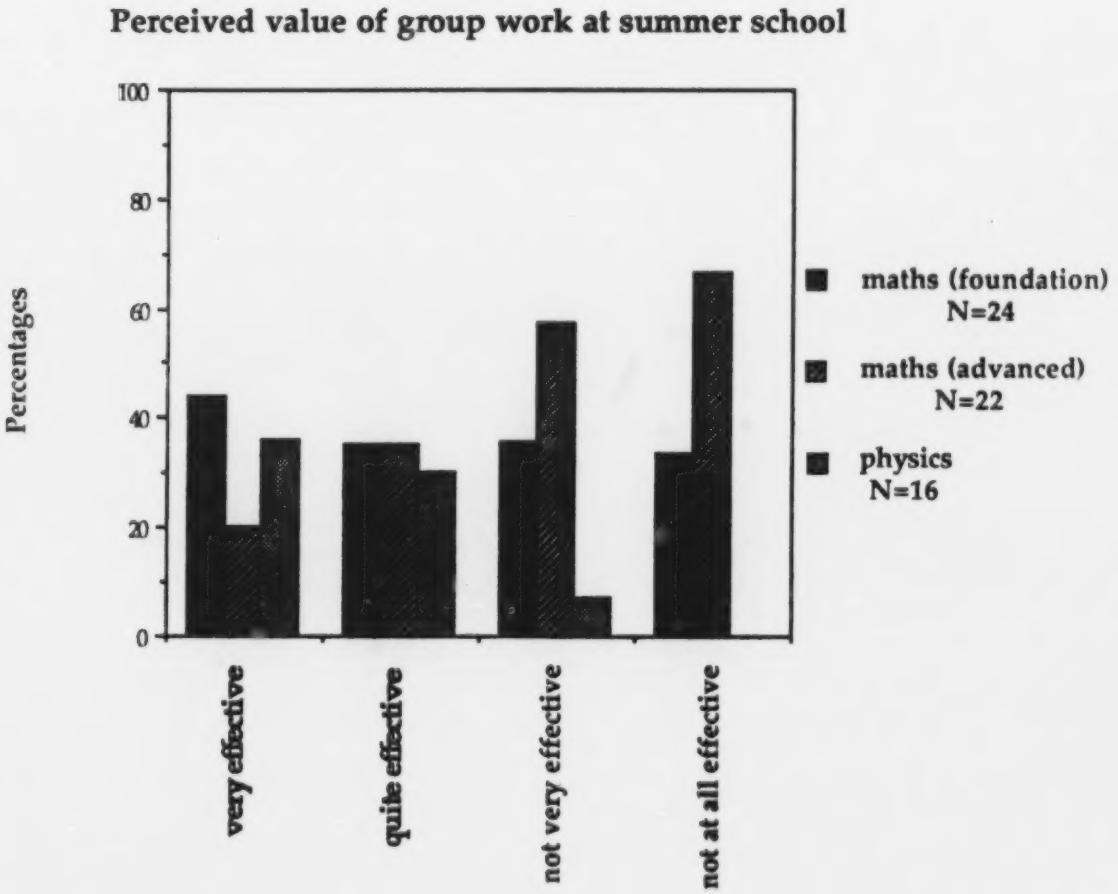
Perceived value of group work at summer school
Percentages
100
80
60
40
20
0
very effective
quite effective
not very effective
not at all effective
maths (foundation)
N=24
maths (advanced)
N=22
physics
N=16

Figure 3

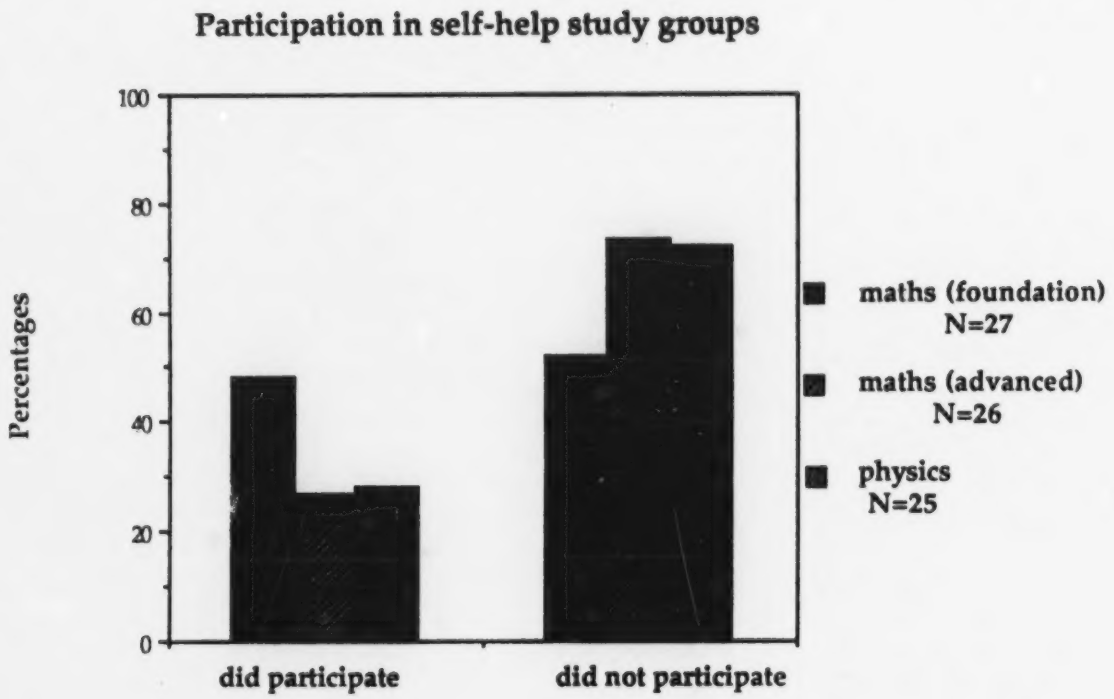
Participation in self-help study groups
Percentages
100
80
60
40
20
0
did participate
did not participate
maths (foundation)
N=27
maths (advanced)
N=26
physics
N=25

Figure 4

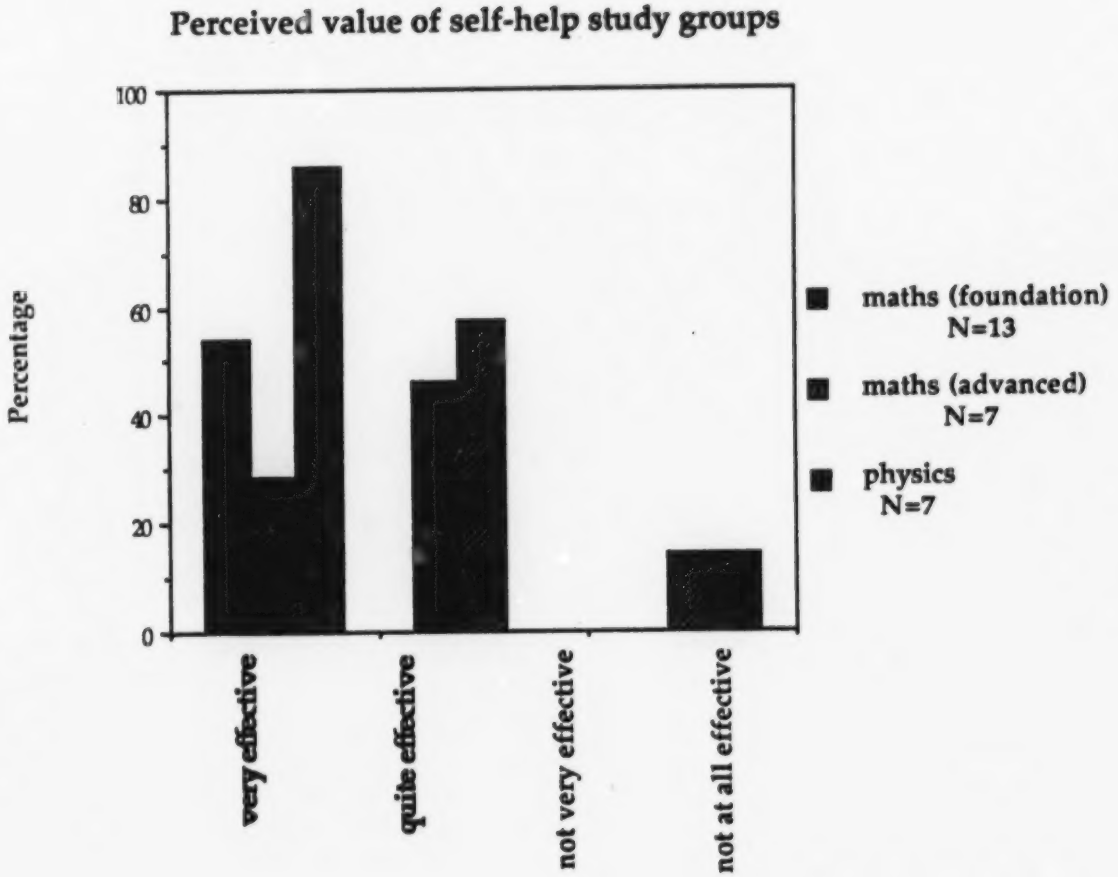
Perceived value of self-help study groups
Percentage
100
80
60
40
20
0
very effective
quite effective
not very effective
not at all effective
maths (foundation) N=13
maths (advanced) N=7
physics N=7

Figure 7

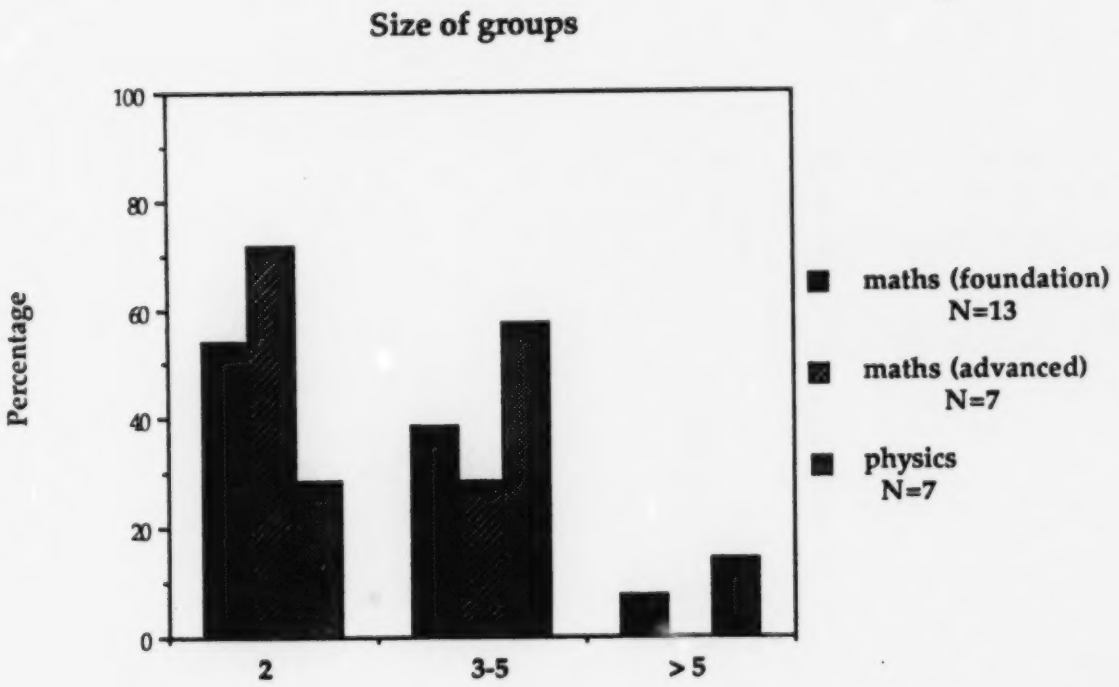
Size of groups
Percentage
100
80
60
40
20
0
2
3-5
>5
maths (foundation)
N=13
maths (advanced)
N=7
physics
N=7

Figure 6

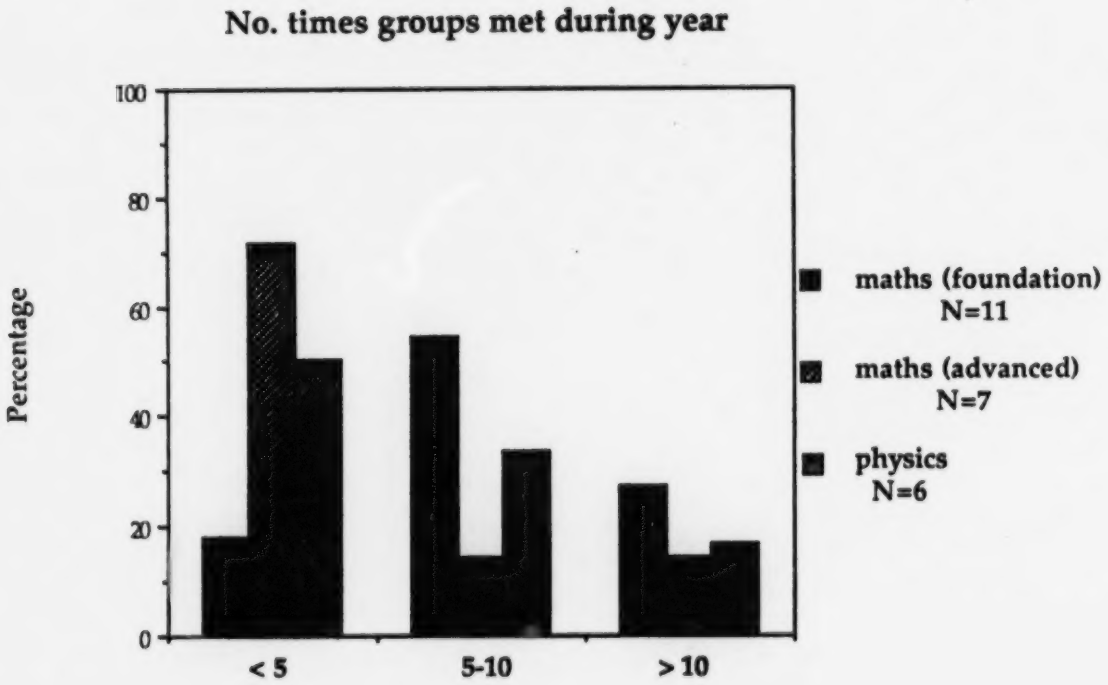
No. times groups met during year
Percentage
100
80
60
40
20
0
< 5
5-10
> 10
maths (foundation)
N=11
maths (advanced)
N=7
physics
N=6

Figure 5

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